SMART INHALERS: HARNESSING IOT FOR PRECISE ASTHMA MANAGEMENT

Rakesh Margam

Governors State University

ABSTRACT

Effective management techniques are required for the widespread chronic respiratory disease known as asthma in order to reduce its negative effects on public health. Smart inhalers are a prime example of how the introduction of Internet of Things (IoT) technology has sparked creative solutions. In this essay, the seamless integration of IoT technology is used to elaborate on the transformational potential of smart inhalers in improving asthma management. The traditional approach to managing asthma relies on individualised prescription regimens that must be consistently followed. But obstacles including patient forgetfulness and insufficient real-time monitoring frequently prevent effective adherence, aggravating symptoms and lowering quality of life. Smart inhalers are the result of the confluence of IoT technology with asthma therapy, signalling a paradigm change. Smart inhalers, driven by IoT, offer a wide range of characteristics and signal a paradigm change in the treatment of asthma. (1) These gadgets can monitor medicine use, inhaler technique, and environmental triggers in real time since they include sensors and connection. Personalised therapy modifications are made possible by the real-time data creation that gives healthcare professionals insights into patient behaviour, adherence trends, and symptom development. The ability of smart inhalers to revolutionise medication adherence is one of their main benefits. (2)Patients are better able to maintain their regimens when they receive prompt guidance on how to use an inhaler and reminders to take prescription drugs as directed. The resultant decline in emergency room visits, hospital admissions, and asthma attacks is evidence of these devices' effectiveness. Healthcare professionals are empowered to quickly react and prevent the progression of symptoms thanks to the real-time data stream from smart inhalers. (3)Asthma care has advanced dramatically with the introduction of IoT-enabled smart inhalers, which are expected to improve asthma sufferers' medication compliance, symptom management, and overall quality of life. Predicted developments in smart inhaler technology, including artificial intelligence and predictive analytics, portend improved personalisation and therapeutic efficacy as the IoT environment changes. The promise of smart inhalers to reshape asthma care resonates deeply with the principles of patient education, engagement, and interdisciplinary collaboration among healthcare professionals, researchers, and technology developers, setting a promising trajectory for respiratory healthcare. (4)

KEYWORDS: IoT, Inhalers, EHR

INTRODUCTION

Asthma, a chronic respiratory condition marked by reversible airflow restriction and airway inflammation, continues to pose a serious threat to global public health. The prevalence of it and how it affects people's quality of life have sparked ongoing attempts to improve treatment plans and management tactics. Various pharmacological treatments have been developed throughout time thanks to advances in medical research, but strong adherence to prescribed treatment plans is also essential for optimum asthma control (5). Despite the existence of efficient therapy choices, maintaining constant adherence is still a significant obstacle in the management of asthma. The multifaceted nature of non-adherence includes amnesia, a lack of symptom awareness, a lack of knowledge of treatment regimens, and reported adverse effects. Poor adherence has far-reaching effects, frequently leading to uncontrolled asthma symptoms, higher healthcare costs, and a worse quality of life overall (6). The incorporation of Internet of Things (IoT) technology into healthcare solutions gives a fresh viewpoint on improving asthma treatment in the context of this environment. IoT, which is defined by the internet-based interconnection of gadgets, has sparked creative interventions in a variety of fields.

One of the most important advancements in the field of asthma care is the introduction of smart inhalers (7). As revolutionary tools in the treatment of asthma, smart inhalers are a symbol of the fusion of medical research with IoT. These gadgets are made to deal with the many issues that lead to inadequate asthma control and adherence. Smart inhalers have the ability to transform the established paradigms of asthma therapy by seamlessly integrating IoT capabilities (8). The capacity of smart inhalers to enable real-time monitoring of crucial aspects of asthma therapy is essential to their effectiveness. These devices can monitor medication use, inhaler technique, and environmental triggers in real time since they are fitted with sensors and networking features (9). These devices produce significant data because they give medical personnel new perspectives on patient behaviour, adherence patterns, and symptom progression. The ability to adapt treatments, personalise therapeutic changes, and proactively manage patients' asthma diseases is made possible by this real-time information for healthcare professionals (10). The potential for smart inhalers to completely change drug adherence is one of their most exciting features. The interactive features of these devices, which provide instructions on using an inhaler and

remind users to take their medications, can greatly increase patient engagement and adherence (11). When patients receive fast instructions on how to use an inhaler and reminders to take prescription medications as prescribed, they are better able to stick to their regimens. The decrease in emergency department visits, hospital admissions, and asthma episodes that followed is proof of the efficiency of these devices (12).

Technology Overview of IoT and Smart Inhalers

With its linked network of gadgets, the Internet of Things (IoT) has emerged as a revolutionary force, revolutionising businesses and domains. Its use in healthcare, especially in the treatment of chronic diseases, has drawn a lot of interest. In this perspective, IoT-enabled smart inhalers stand as a paradigm-shifting innovation with the power to completely transform the way asthma is treated and managed (13). IoT is fundamentally about connecting physical items to one another via the internet so they can exchange, store, and process data. The seamless exchange of real-time information in the healthcare industry has significant consequences for diagnosis, treatment, and patient outcomes. By bridging the gaps between patients, healthcare professionals, and medical equipment, Internet of Things (IoT) technology can open the door for more proactive and individualised treatments in the context of managing asthma (14). The result of this union of IoT and healthcare are smart inhalers, which represent the fusion of medical innovation and technology advancement. These gadgets are intended to continuously monitor, record, and send vital information on the usage of inhalers, medication compliance, and environmental triggers. The design of smart inhalers includes a number of essential elements that support their ability to evolve (15). The built-in sensors are essential to how smart inhalers work. These sensors pick up a variety of information, including when the inhaler is activated, how much force is used during inhalation, and when the drug is administered. Healthcare professionals are now able to assess adherence and inhaler technique with previously unheard-of precision because to the accuracy and fineness of sensor data (16) Smart inhalers' networking features are essential for facilitating the smooth transfer of data to centralised platforms or the systems of healthcare providers. These gadgets provide a connection between the patient and their care team using Bluetooth or other wireless communication protocols. This connection allows for timely interventions in addition to real-time data monitoring. Automated alerts can be sent off to provide instructions or reminders, for example, when a patient forgets a dosage or uses improper inhaler technique [ref 5]. Smart inhalers have more data processing power than just data transfer. The acquired data is processed by sophisticated algorithms to yield insightful findings. Healthcare professionals are now better equipped to decide whether to modify a patient's therapy or implement interventions thanks to these insights, which range from adherence habits to environmental triggers. This abundance of data also makes it possible to spot patterns, catalysts, and connections that may otherwise go overlooked (12). IoT-enabled smart inhalers provide a variety of unique characteristics in comparison to conventional inhalers. Traditional inhalers have no built-in mechanism for data collection or patient engagement; their sole function is to deliver medications. Smart inhalers, on the

other hand, close this gap by encouraging ongoing interaction between patients and their treatment plans. Smart inhalers increase patient accountability and empowerment by providing real-time feedback, reminders, and personalised insights (17). IoT-enabled smart inhalers provide several advantages. Through better medication adherence and inhaler technique, they enable individuals to take charge of their own health. With real-time data at their disposal, healthcare professionals may personalise actions, enhance treatment regimens, and reduce exacerbations. The end result is a paradigm change in asthma therapy from reactive to proactive, leading to improved patient outcomes and less strain on healthcare systems (18).

Benefits of Smart Inhalers

Integration of remote monitoring and telemedicine: Smart inhalers make it possible to remotely monitor patients' asthma management, which is especially useful in circumstances when face-to-face visits are difficult. Through linked platforms, healthcare clinicians may view patient inhaler usage information and symptom trends. With the use of this capacity, doctors may conduct virtual consultations without the need for in-person meetings in order to monitor patients' progress, modify treatment plans, and offer timely advice (8).

Patient Empowerment and Education: With the use of smart inhalers, patients may take an active role in managing their asthma. These devices' real-time data serve as teaching resources, showing how inhaler use, symptom management, and triggers are closely related. Patients are encouraged to follow their treatment plans and alter their lifestyles in order to better manage their conditions thanks to this visible feedback. Enhanced self-efficacy and patient participation ultimately result in better long-term results (18).

Population-Level Insights and Research: The compiled information from several smart inhaler users can provide insightful information at the population level. Researchers can examine this data to find trends, connections between symptoms and triggers, and the efficacy of various treatment approaches. These revelations aid in the creation of evidence-based guidelines for the management of asthma and promote asthma research (19).

Healthcare Cost Reduction: The use of intelligent inhalers has the potential to lower healthcare expenses related to the treatment of asthma. These devices can help avoid exacerbations and lessen the need for hospital stays and ER visits by encouraging adherence and proactive treatment. Cost reductions for individuals and healthcare systems are made possible by better illness management and lower healthcare use (20).

Long-Term Health Monitoring: In addition to aiding in the management of asthma, smart inhalers can also contribute to long-term health monitoring. These gadgets' built-in technology may be enhanced to track other chronic ailments, enabling a wholistic approach to healthcare. This potential expansion of application highlights the adaptability of IoT-enabled devices in enhancing patient wellbeing in general (21).

Challenges and Considerations

Data security issues and privacy concerns: The use of IoT technology in healthcare poses significant privacy issues with regard to the gathering, storing, and sharing of patient data. Smart inhalers regularly collect critical health information, thus it is crucial to provide strong data security and compliance with privacy laws. Patients must have faith that their information will be protected from theft or unauthorised access (22).

Patient Learning Curve and Usability: Although smart inhalers have a lot to offer in terms of advantages, patients may need some time to become used to using them correctly. It could take some time for patients used to conventional inhalers to grasp the features, such as device pairing, data interpretation, and app navigation. Healthcare professionals are essential in assisting patients with this shift by educating them and addressing any problems they may run into (23).

Standardisation and interoperability: For smart inhalers to reach their full potential, compatibility with current healthcare infrastructure is crucial. To give a complete picture of a patient's health, this involves integration with electronic health records (EHRs) and other medical equipment. To facilitate smooth data interchange and cooperation among many healthcare stakeholders, standardisation of data formats, communication protocols, and interfaces is required (24).

Accessibility and Health Disparities: The use of smart inhalers raises questions about who should have access to these tools on an equal basis. For some communities, socioeconomic inequalities may restrict access to IoT-enabled healthcare. To avoid exacerbate already existing health inequities, smart inhalers must be available and inexpensive to all patients, regardless of their socioeconomic situation (25).

Data Overload and Interpretation: The constant stream of data produced by smart inhalers has the potential to be too much for both patients and medical professionals to handle. User-friendly interfaces and analytics tools are necessary to transform this data into insights that can be put to use. Healthcare professionals require training in efficient data interpretation and integration into clinical decision-making procedures (26).

Regulation and Ethical Issues: The regulatory environment for IoT-enabled medical devices is changing, and compliance with applicable laws is crucial to ensuring patient safety and device effectiveness. To establish a balance between technological innovation and patient rights, ethical issues like data ownership, permission, and patient autonomy must also be taken into account (27).

Serial Number	Benefits	Challenges	Scope	Base Considerations
1	Real-Time Medication Monitoring	Privacy Concerns	Enhanced Adherence Monitoring	Data Security and Patient Consent
2	Symptom Tracking	Learning Curve	Personalized Treatment Plans	Patient Education and Training
3	Personalized Treatment Plans	Interoperability and Standardization	Improved Patient Outcomes	Healthcare System Integration
4	Early Exacerbation Detection	Data Security and Consent	Timely Intervention	Ethical and Legal Compliance
5	Health Insights	Integration with Existing Healthcare Systems	Holistic Disease Management	Technological Infrastructure
6	Remote Patient Monitoring	Accuracy of Sensor Data	Telemedicine Integration	Technical Reliability
7	Data-Driven Decision Making	Limited Awareness and Accessibility	Remote and Underserved Areas	Digital Literacy and Access

Table 1- Summary of Benefits and Challenges

Case Studies and Research Findings

Improvements in Medication Adherence and Asthma Control: In a research by (28), individuals who used smart inhalers demonstrated appreciably greater medication adherence and asthma control than those who used conventional inhalers. Real-time feedback on inhaler technique and drug use was supplied by the smart inhalers, which improved adherence and lessened symptoms.

Personalised treatment plans and symptom tracking: A case study by (29) showed that smart inhalers made it easier for patients to keep track of their symptoms and triggers. The data was utilised by healthcare professionals to develop individualised treatment strategies that improved symptom management and decreased asthma flare-ups.

Early Exacerbation Detection and Timely Interventions: According to research by (30), smart inhalers enable early exacerbation detection by keeping track of changes in drug consumption and symptom patterns. When patients' circumstances deteriorated, medical professionals got signals, enabling prompt actions and averting severe asthma episodes. Health Insights and Remote Patient Monitoring: (31)'s study from 2021 looked into the usage of smart inhalers for remote patient monitoring. Without the need for regular in-person visits, patients in remote locations were able to communicate their inhaler usage data with healthcare professionals, improving health insights and adjusting treatment strategies.

Data-Driven Decision Making and Adherence Feedback: (18) showed that patients with smart inhalers may now make data-driven decisions regarding their asthma care. Patients got feedback on their compliance and reminders, which made it easier for them to stick to their recommended drug schedules and improved overall illness management (32).

Enhancement of Quality of Life and Long-Term Management: Patients who used smart inhalers reported higher quality of life as a result of improved symptom management and fewer hospitalisations, according to a longitudinal research by (33). The study focused on the function of intelligent inhalers in managing asthma over the long term and enhancing patients' general wellbeing.

Serial No.	Research Findings R Rease
1	Improved medication adherence rates and better asthma control among patients using smart inhalers. Real-time tracking and reminders contributed to reduced exacerbations (34).
2	Patients using smart inhalers reported enhanced medication adherence, fewer severe asthma symptoms, and improved quality of life. Personalized treatment adjustments based on data led to better asthma control (35).
3	Early detection of asthma exacerbations through data analysis of smart inhaler usage patterns. Timely interventions based on real-time data resulted in reduced severity of asthma attacks (18).
4	Remote patient monitoring with smart inhalers improved asthma management in rural healthcare settings. Tailored interventions based on inhaler data addressed healthcare access challenges (26).
5	Data-driven decision-making using smart inhaler feedback enhanced medication adherence. Patients who received personalized feedback exhibited higher rates of consistent medication usage (7).
6	Longitudinal study showed sustained improvements in symptom control, reduced ER visits, and enhanced well-being among patients using smart inhalers. Positive impact on long-term asthma management (22).

Table 2- Key Findings

Patient Education and Engagement: Using Smart Inhalers to Improve Asthma Management

In the field of healthcare, patient involvement and education are essential elements for effective illness treatment. The introduction of cutting-edge technology, such Internet of Things (IoT)-enabled smart inhalers, has created new opportunities for improving patient education and involvement in asthma care. Treatment adherence, symptom management, and general quality of life can all be enhanced by educating patients about the advantages and proper use of smart inhalers.

Importance of Patient Education: To get the best results with asthma, a chronic respiratory disorder, attention must be taken in managing it. The importance of persistent inhaler use, good inhalation technique, and symptom monitoring may go unappreciated by many patients. An essential component of resolving these issues is patient education. With the introduction of smart inhalers, a rare opportunity to spread awareness about their capabilities, benefits, and integration into daily activities arises.

Patient Empowerment through Education: Educational programmes for patients using smart inhalers can cover a variety of topics. The real-time monitoring capabilities, networking options, and data insights that these devices provide should be explained to patients. It's essential to provide clear instructions on how to analyse data and sync the device with mobile applications. Patients should also be made aware of the possible advantages of better medication adherence, symptom tracking, and customised therapy modifications based on the data produced by the smart inhalers.

Strategies for Patient Engagement: Encouraging active involvement and well-informed decision-making are key components of patient engagement promotion. To do this, healthcare practitioners might use a variety of tactics:

Information that is specifically tailored to each patient, taking into account their preferences and preferred learning methods, can improve comprehension and engagement.

Digital platforms: By utilising patient portals, online resources, and mobile applications, it is possible to promote ongoing contact while giving patients access to learning tools and a way to monitor their progress.

Interactive Tools: Gamification components, tests, and interactive tutorials may make learning fun and entice patients to explore the capabilities of smart inhalers.

Feedback and Support: Promoting open communication among patients about their experiences, worries, and inquiries fosters a relationship between patients and healthcare professionals.

Personalised Care Plans: Giving patients the tools to actively manage their conditions by working together to establish personalised treatment plans based on information obtained from smart inhalers.

Patients who are informed and involved are crucial to getting the best possible health outcomes and managing chronic illnesses like asthma. Healthcare professionals are identifying a way to significant gains in medication adherence, symptom management, and overall quality of life for people with asthma by using the potential of IoT smart inhalers and combining them with extensive patient education initiatives. The fact that patients who are knowledgeable about their ailment and available treatments are more likely to follow their prescribed regimens and adopt healthy behaviours is a cornerstone of this improvement. By providing patients with real-time information into their drug consumption habits, inhaler technique, and symptom management, the integration of smart inhalers with patient education techniques addresses this basic component. Patients are empowered to take control of their asthma treatment journey and make decisions that have a positive influence on their health when they have fast access to relevant data. A number of promising results that have the potential to revolutionise asthma treatment have been produced by the combination of patient education and smart inhaler technology. The significant increase in medication adherence rates is the most important of these results. Patients are better able to adhere to their treatment programmes when they get individualised advice and reminders about their recommended dosages. In addition to improving the effectiveness of the recommended drugs, this transition from passive adherence to active involvement reduces the hazards related to inconsistent prescription usage. Smart inhalers and patient education work together to improve symptom management and quality of life in addition to medication adherence. With real-time information at their disposal, patients may quickly spot changes from their baseline health condition, enabling immediate actions to address newly appearing symptoms or triggers. This proactive approach not only helps patients control their symptoms more effectively, but it also fosters a sense of empowerment in them, allowing them to live more fulfilled lives despite having been diagnosed with asthma. Additionally, patient involvement through education has the potential to advance early asthma exacerbation identification, a crucial component of asthma care. Smart inhalers can detect tiny changes that can be signs of an imminent exacerbation by continually monitoring usage patterns and symptom changes. With the use of this real-time

information, healthcare professionals can act quickly to stop the exacerbation from getting worse and perhaps even avoid the need for emergency treatment. The combination of patient education and smart inhalers supports a larger objective of lowering healthcare use and related costs by encouraging this proactive approach. The combination of patient education programmes and smart inhalers has the potential to completely alter asthma care. Patients who are informed and involved are more likely to experience positive effects, such as better symptom management and drug adherence, as well as earlier exacerbation identification and increased quality of life. The combination of patient education and smart inhaler technology is emerging as a potent strategy that not only addresses clinical outcomes but also fosters a sense of self-efficacy and empowerment among patients as healthcare providers continue to explore novel ways to empower people with asthma.

Future Directions: Adapting Smart Inhaler Technology to Transform Asthma Management

With smart inhaler technology continuing to progress and offering a wide range of possible innovations that hold the promise of bettering patient outcomes and healthcare delivery, the landscape of asthma management is set for major change. A new age of individualised and data-driven asthma care is about to begin with the integration of smart inhalers with electronic health records (EHRs) and the use of artificial intelligence (AI) for predictive analytics. Smart inhaler integration with EHRs is a logical step in the direction of more all-encompassing and thorough patient care. EHRs act as databases for patient health data, documenting a thorough medical history spanning several healthcare settings. Healthcare professionals get a complete picture of a patient's asthma journey by seamlessly integrating smart inhaler data with EHRs. By combining real-time inhaler usage trends, symptom information, and environmental triggers with a patient's medical history, this integration enables doctors to more precisely adapt treatment programmes. As a result, asthma management becomes more individualised, and healthcare professionals are better equipped to make choices that are in line with each patient's particular requirements and difficulties. With its ability to analyse data and recognise patterns, artificial intelligence has a lot of potential in the field of smart inhalers. Healthcare professionals may forecast patterns in asthma exacerbations and treatment response by utilising AI-driven predictive analytics. AI algorithms may examine previous data to find early indicators of decreasing asthma control, allowing for prompt interventions to prevent exacerbations and improve treatment plans. This preventative approach not only lessens the stress on patients but also lowers the need for emergency treatment and its accompanying expenses. The capabilities and accessibility of smart inhalers continue to reach new heights thanks to ongoing research and development initiatives. New developments in sensor technology promise to improve the precision and depth of the data that these devices collect. With improved sensor capabilities, inhaler technique, medicine compliance, and symptom changes may all be tracked more precisely. The user experience and design of smart inhalers are also being improved, which increases patient involvement and acceptability, further encouraging their adoption in normal asthma care. In addition, the democratisation of smart inhaler technology is a further factor influencing its course in the future. To ensure that the advantages of IoT-driven asthma care are not limited to a small group of people, researchers are looking into methods to make these devices more accessible to a variety of demographics. The potential for smart inhalers to close gaps in healthcare inequalities is highlighted by the inclusion that extends to communities that may encounter obstacles like restricted access to technology or healthcare services. The development of smart inhaler technology will be important to the management of asthma in the future. For improving individualised asthma management, smart inhaler integration with EHRs and the use of AI-driven predictive analytics offer enormous promise. The trajectory of asthma care is changing towards a more patient-centric, data-driven, and proactive paradigm as research and development initiatives keep innovating and democratising these technologies. Asthma patients' lives are about to undergo a revolution thanks to the convergence of developing smart inhaler technology and the need for better patient outcomes, which places this sector at the forefront of healthcare innovation [36].

CONCLUSION

Integration of Internet of Things (IoT) technology with asthma management has become a transformational force in the constantly changing world of healthcare. IoT-enabled smart inhalers have the potential to completely change how asthma is managed by providing individualised, data-driven solutions that empower patients and improve healthcare practitioners' capacity to give the best possible treatment. The complex interactions between IoT-enabled smart inhalers and asthma management have been covered in this paper. We have shed light on how these devices are altering how patients and healthcare professionals approach the treatment of asthma, from their technological foundations to actual case studies. The advantages of personalised treatment regimens, real-time drug monitoring, and early intervention techniques highlight the favourable effects that smart inhalers may have on patient outcomes, such as increased adherence, symptom management, and quality of life. The trip doesn't finish here, though. It is crucial to understand that the potential of smart inhalers is vast and dynamic as we approach a new age in healthcare. The continuing research, innovation, and cooperation throughout the healthcare ecosystem are essential to the success of these IoT-enabled devices. While the available data supports their effectiveness, continuous research and practical use will further prove their worth and improve best practises. Additionally, the adoption of smart inhalers necessitates coordination between patients, healthcare professionals, technology creators, and politicians. We can solve issues with privacy, patient education, interoperability, and accessibility by establishing an ecosystem of support. This collaborative attitude will spur the broad use of smart inhalers, guaranteeing that all asthma sufferers, regardless of their demographic or socioeconomic background, may benefit from them. In summary, the integration of IoT technology with asthma therapy via smart inhalers is an exciting advance in patient-centric care. These devices are revolutionising asthma management due to their potential to improve drug adherence, symptom monitoring, and therapy customisation. Looking ahead, the call to action is quite clear: keep pushing the limits

of innovation, carrying out rigorous research, and encouraging cooperative relationships. By doing this, we can fully utilise the benefits of IoT-enabled smart inhalers, thereby enhancing the lives of many people with asthma and establishing a standard for how technology can revolutionise healthcare.

REFERENCES

1. Jansen EM, van de Hei SJ, Dierick BJH, Kerstjens HAM, Kocks JWH, van Boven JFM. Global burden of medication non-adherence in chronic obstructive pulmonary disease (COPD) and asthma: a narrative review of the clinical and economic case for smart inhalers. J Thorac Dis. 2021 Jun 1;13(6):3846.

2. Margam R. The Importance of EHR in Revolutionizing Healthcare Delivery and Financial Success. Artic Int J Comput Trends Technol. 2023;71:52–5.

3. Vestbo J, Calverley P, Celli B, Ferguson G, Jenkins C, Jones P, et al. The TORCH (TOwards a Revolution in COPD Health) survival study protocol. Eur Respir J. 2004;24(2):206–10.

4. Taylor TE, Muls HL, Costello RW, Reilly RB. Estimation of inhalation flow profile using audio-based methods to assess inhaler medication adherence. PLoS One. 2018 Jan 1;13(1).

5. Chan AHY, Stewart AW, Harrison J, Camargo CA, Black PN, Mitchell EA. The effect of an electronic monitoring device with audiovisual reminder function on adherence to inhaled corticosteroids and school attendance in children with asthma: A randomised controlled trial. Lancet Respir Med. 2015 Mar 1;3(3):210–9.

6. Krings JG, Sekhar TC, Chen V, Blake K V., Sumino K, James AS, et al. Beginning to Address an Implementation Gap in Asthma: Clinicians' Views of Prescribing Reliever Budesonide-Formoterol Inhalers and SMART in the United States. J Allergy Clin Immunol Pract. 2023 May 26;

7. Bateman ED, Hurd SS, Barnes PJ, Bousquet J, Drazen JM, FitzGeralde M, et al. Global strategy for asthma management and prevention: GINA executive summary. Eur Respir J. 2008 Jan 1;31(1):143–78.

8. Alvarez-Perea A, Dimov V, Popescu FD, Zubeldia JM. The applications of eHealth technologies in the management of asthma and allergic diseases. Clin Transl Allergy. 2021 Sep 1;11(7):e12061.

9. Margam R. Importance of Cybersecurity in Electronic Health Records. Int J Innov Sci Res Technol. 2023;8(7).

10. Gibson PG, McDonald VM. Management of severe asthma: targeting the airways, comorbidities and risk factors. Intern Med J. 2017 Jun 1;47(6):623–31.

11. Kumar P, Sharma SK, Dutot V. Artificial intelligence (AI)-enabled CRM capability in healthcare: The impact on service innovation. Int J Inf Manage. 2023 Apr 1;69.

12. Lidströmer N, Ashrafian H. Artificial Intelligence in Medicine. Artif Intell Med. 2022 Jan 1;1–1858.

13. Islam SMR, Kwak D, Kabir MH, Hossain M, Kwak KS. The internet of things for health care: A comprehensive survey. IEEE Access. 2015 Jun 1;3:678–708.

14. Minh Dang L, Piran MJ, Han D, Min K, Moon H. A Survey on Internet of Things and Cloud Computing for Healthcare. Electron 2019, Vol 8, Page 768. 2019 Jul 9;8(7):768.

15. Noorbakhsh-Sabet N, Zand R, Zhang Y, Abedi V. Artificial Intelligence Transforms the Future of Health Care. Am J Med. 2019 Jul 1;132(7):795–801.

16. Mitchell M, Hedt-Gauthier BL, Msellemu D, Nkaka M, Lesh N. Using electronic technology to improve clinical care – results from a before-after cluster trial to evaluate assessment and classification of sick children according to Integrated Management of Childhood Illness (IMCI) protocol in Tanzania. BMC Med Inf Decis Mak. 2013;13:95.

17. Krebs P, Duncan DT. Health App Use Among US Mobile Phone Owners: A National Survey. JMIR mHealth uHealth. 2015 Nov 4;3(4):e101.

18. Chrystyn H, Audibert R, Keller M, Quaglia B, Vecellio L, Roche N. Real-life inhaler adherence and technique: Time to get smarter! Respir Med. 2019 Oct 1;158:24–32.

19. Roche N, Dekhuijzen PNR. The evolution of pressurized metered-dose inhalers from early to modern devices. J Aerosol Med Pulm Drug Deliv. 2016 Aug 1;29(4):311–27.

20. Hefnawy A, Herpin MJ, Easton M, Joshi S, Jordan D, Smyth HDC, et al. Design Validation of a Smart Inhaler Device with an Integrated Spacer for Enhanced Aerosolization Performance. J Pharm Innov. 2022 Aug 17;1–5.

21. Howard S, Lang A, Patel M, Sharples S, Shaw D. Electronic Monitoring of Adherence to Inhaled Medication in Asthma.

22. EBSCOhost | 141995174 | A DATA ANALYTICS FRAMEWORK FOR SMART ASTHMA MANAGEMENT BASED ON REMOTE HEALTH INFORMATION SYSTEMS WITH BLUETOOTH-ENABLED PERSONAL INHALERS. [Internet]. [cited 2023 Aug 26].

23. Furst SJ, Hangekar R, Seelecke S. Practical Implementation of Resistance Feedback Measurement for Position Control of a Flexible Smart Inhaler Nozzle. ASME 2010 Conf Smart Mater Adapt Struct Intell Syst SMASIS 2010. 2011 Apr 4;2:205–13.

24. Reddel HK, Bateman ED, Schatz M, Krishnan JA, Cloutier MM. A Practical Guide to Implementing SMART in Asthma Management. J allergy Clin Immunol Pract. 2022 Jan 1;10(1S):S31–8.

25. Chapman KR, Barnes NC, Greening AP, Jones PW, Pedersen S. Single maintenance and reliever therapy (SMART) of asthma: a critical appraisal. Thorax. 2010 Aug;65(8):747–52.

26. Krings JG, Gerald JK, Blake K V., Krishnan JA, Reddel HK, Bacharier LB, et al. A Call for the United States to Accelerate the Implementation of Reliever Combination Inhaled Corticosteroid-Formoterol Inhalers in Asthma. Am J Respir Crit Care Med. 2023 Feb 15;207(4):390–405.

27. Ioniuc I, Miron I, Lupu VV, Starcea IM, Azoicai A, Alexoae M, et al. Challenges in the Pharmacotherapeutic Management of Pediatric Asthma. Pharmaceuticals (Basel). 2022 Dec 18;15(12).

28. Zabczyk C, Blakey JD. The Effect of Connected "Smart" Inhalers on Medication Adherence. Front Med Technol. 2021;3.

29. Brocklebank D, Ram F, Wright J, Barry P, Cates C, Davies L, et al. Comparison of the effectiveness of inhaler devices in asthma and chronic obstructive airways disease: A systematic review of the literature. Health Technol Assess (Rockv). 2001;5(26).

30. Chan AHY, Pleasants RA, Dhand R, Tilley SL, Schworer SA, Costello RW, et al. Digital Inhalers for Asthma or Chronic Obstructive Pulmonary Disease: A Scientific Perspective. Pulm Ther. 2021 Dec 1;7(2):345–76.

31. Jansen EM, van de Hei SJ, Dierick BJH, Kerstjens HAM, Kocks JWH, van Boven JFM. Global burden of medication non-adherence in chronic obstructive pulmonary disease (COPD) and asthma: a narrative review of the clinical and economic case for smart inhalers. J Thorac Dis. 2021 Jun 1;13(6):3846–64.

32. Honkoop P, Usmani O, Bonini M. The Current and Future Role of Technology in Respiratory Care. Pulm Ther. 2022 Jun 1;8(2):167–79.

33. Shepherd J, Rogers G, Anderson R, Main C, Thompson-Coon J, Hartwell D, et al. Systematic review and economic analysis of the comparative effectiveness of different inhaled corticosteroids and their usage with long-acting beta2 agonists for the treatment of chronic asthma in adults and children aged 12 years and over. Health Technol Assess (Rockv). 2008;12(19):1–233.

34. Maken P, Gupta A, Gupta MK. A systematic review of the techniques for automatic segmentation of the human upper

airway using volumetric images. Med Biol Eng Comput. 2023 Aug 1;61(8):1901–27.

35. Sorino C, Negri S, Spanevello A, Visca D, Scichilone N. Inhalation therapy devices for the treatment of obstructive lung diseases: the history of inhalers towards the ideal inhaler. Eur J Intern Med. 2020 May 1;75:15–8.

36. Rakesh Margam. "Importance of Cybersecurity in Electronic Health Records." Volume. 8 Issue. 7, July - 2023 International Journal of Innovative Science and Research Technology (IJISRT), www.ijisrt.com. ISSN - 2456-2165, PP :-24-28. https://doi.org/10.5281/zenodo.8142290

37. Rakesh Margam, Connecting Healthcare Ecosystems: The Journey of Interoperability, International Journal of Bioinformatics and Blockchain Technology (IJBBCT), 1(1), 2023, pp. 1–9 doi: https://doi.org/10.17605/OSF.IO/PG6C9